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Potato Farming in The Andes: Some Lessons from On-Farm Research in Peru's Mantaro Valley

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SUMMARY

Development programs generally assume that agricultural researchers and extensionists are sufficiently knowledgeable about local farming systems and technological alternatives to allow them to formulate sound recommendations for farmers. This paper, based on applied farming systems research in highland Peru, presents a case in which such conventional wisdom proved to be highly erroneous. As a result, use of the technology which researchers and extensionists recommended most highly (improved seed) reduced farmers' net returns. In contrast, another technology which was considered to be less important (improved pest control) was found to be highly profitable. The interdisciplinary approach used, employing surveys, observations and farm-level experimentation, could be used in many types of agricultural development program to identify key problems and pre-screen potential solutions.

INTRODUCTION

From 1977 to 1980 the International Potato Center (CIP) conducted, with Peru's National Potato Program, a sequence of farmer surveys and on-farm experiments in highland Peru under the umbrella of 'The Mantaro Valley Project'. Interdisciplinary research activities included a review of literature on Andean agriculture, a baseline survey of ecology and agricultural land use, single- and multiple-visit producer surveys, and in-depth farm-level research on three technological problem areas of particular concern to CIP and to Peru's National Potato Program:

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agronomic constraints to potato production, post-harvest technology (storage and processing) and seed potato production and distribution (Horton, 1983). This paper presents results of research on agronomic production constraints. Rhoades & Booth (1982*a*, *b*) and Monares (1981, 1982) present additional results of research on post-harvest technology and seed systems, respectively.

Two objectives of the constraints research were to improve understanding of Andean potato agriculture and to test the economic viability of recommended practices under representative farming conditions.

The literature review turned up very little information on agricultural practices or performance of alternative technologies on farmers' fields (Werge, 1977). Hence, we were obliged to use a series of beliefs commonly held by local potato researchers and extensionists as the starting point for the Mantaro Valley studies. These beliefs can be summarized as follows:

> First, production technology and yields are closely linked to farm size. Large commercial farmers produce intensively, using tractors, high-yielding varieties and heavy doses of chemical fertilizer and pesticides. In contrast, small subsistence farmers employ traditional low-yielding technologies.
>
> Secondly, the modern, high-input systems are inherently more profitable than the traditional, low-input systems.
>
> Thirdly, the most critical yield constraint is poor quality seed.
>
> Fourthly, if recommended practices were applied by small farmers they could double or triple their yields and substantially increase their incomes. These recommended practices would cost little or no more than currently applied technology.
>
> Fifthly, small farmers do not adopt recommended practices because they lack information (problems of extension) and or they resist change (problems of social integration and general education).

SURVEY RESULTS*

Land use and agro-ecological zones

Land use in the Mantaro Valley reflects the interaction of two major variables: ecology and type of farming enterprise. Potatoes are grown in

* This section draws heavily on Mayer (1979), Franco *et al.* (1979) and Horton *et al.* (1980).

three agro-ecological zones: the relatively flat land of the *Low Zone* along the Mantaro River (3200–3450 m above sea level); the sloping land of the *Intermediate Zone* (3450–3950 m) and the more steeply sloping fields of the *High Zone* (3950–4200 m). Within the Intermediate Zone two sub-zones can be identified: the humid eastern slopes and the drier western slopes of the Valley (Mayer, 1979).

A wide range of food crops is grown in the Low Zone along the Mantaro River, the most important being maize. As one ascends into the Intermediate and High Zones, fewer and fewer crops can be grown. Maize is seldom found above 3450 m. Tubers (mainly potatoes) predominate on the eastern slopes of the Intermediate Zone; small grains (mainly barley) predominate on the western slopes. In the High Zone, where only the hardiest of plants survive the cold and frost, potatoes are the dominant crop (Figs 1 and 2).

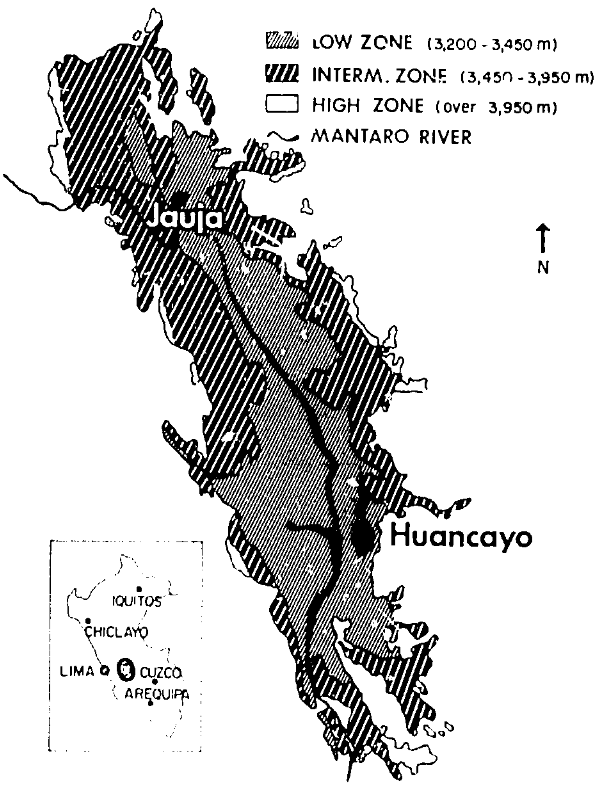

Fig. 1. Agro-ecological zones of the Mantaro Valley. Adapted from Mayer (1979).

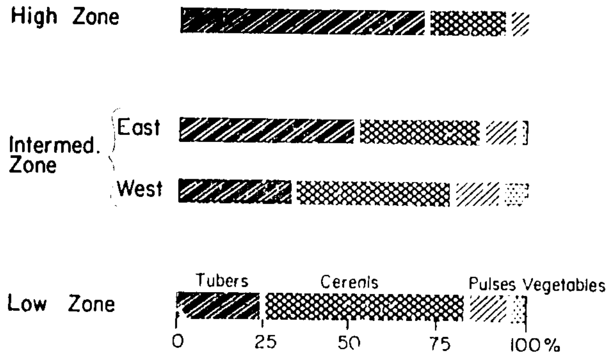

Fig. 2. Use of cropland by agro-ecological zone. Percentages refer to the proportion of land in food crops. Data are from Franco *et al.* (1979).

Intensity of land use is inversely related to altitude. Cropping is most intensive in the Low Zone, particularly on irrigated fields. In the Intermediate and High Zones, cropping intensity declines, fallow appears in the rotation cycles and an increasingly large proportion of land is left in permanent natural pasture.

Nearly 90% of the valley's consumption potatoes are produced on the valley floor and the eastern slopes of the Intermediate Zone. These two favorably endowed agro-ecological zones, with 75% of the valley's potato producers and 80% of the land in potatoes, have higher yields than the High Zone and the western slopes of the Intermediate Zone (Table 1).

TABLE 1
Number of Potato Producers, Area, Production and Yield by Agro-ecological Zone

	Low zone	*Intermediate zone*		*High zone*	*Total valley*
		East	*West*		
Distribution (%)					
Potato producers	51	24	18	7	100
Area in potatotes	49	30	13	8	100
Potato production	55	31	7	6	100
Cropland in potatotes (%)	19	39	22	57	25
Yield (t/ha)	5·5	5·0	2·7	3·6	4·8

Source: Franco *et al.* (1979).

Types of farmers

Small farmers constitute the majority throughout the valley, occupying all possible ecological environments. In the Low Zone a fundamental difference is observed between large and small farmers. Large farmers tend to specialize in commercial potato production, while small farmers operate highly diversified, risk averting, part-time farming systems, growing potatoes mainly for home consumption. This distinction between large and small farmers is less clear in the Intermediate and High Zones where large commercial farmers are virtually absent. In the Intermediate Zone many small farmers market potatoes and barley, the crops which grow best in the area. In the High Zone most farmers derive their cash income from livestock and produce potatoes mainly for home consumption (Table 2).

TABLE 2
Selected Characteristics of Mantaro Valley Potato Farms

	Low zone			*Intermediate zone*		*High zone*
	Large farms	*Medium farms*	*Small farms*	*East*	*West*	
Av. cropland (ha)	74·7	10·9	1·0	1·9	1·8	1·4
Av. in potatoes (ha)	41·9	1·9	0·2	0·7	0·4	0·6
Farmers with off-farm jobs (%)	30	46	80	61	59	63
Potatoes marketed (%)	63	73	11	52	17	26
Inputs purchased (%)	75	61	59	36	27	25

Source: Franco *et al.* (1979) and Horton *et al.* (1980).
Note: Large farms are herein defined as those of large seed growers registered by the Ministry of Agriculture. Medium-sized farms are those producing consumption potatoes on more than 0·5 ha of land. Small farms are those with less than, or equal to, 0·5 ha of land under potatoes.

Nearly every farmer in the Mantaro Valley produces potatoes. The majority of farmers grow less than 1 ha potatoes, but a few large farms have over 100 ha. Large growers' yields are much higher than those of small and medium-sized farmers. As a result, 10% of the valley's farmers produce over half its potatoes and market an even higher percentage. In recent years the degree of concentration of potato production in large farms has increased, despite implementation of Peru's Land Reform.

High production costs and risks have forced small farmers to reduce planting, while large growers with greater risk-taking ability and preferential financial and market arrangements have expanded acreage to supply the growing coastal markets for seed and consumption potatoes.

Both large and small farmers are well integrated into the cash economy. Large farmers purchase most of their inputs and sell most of their output. While small farmers keep a large share of their potatoes for home consumption, they purchase most inputs, including labor. The majority of small farmers also have non-farm sources of income primarily the wages of the male household head (see again Table 2).

Input use

Fertilizer and pesticides

In contrast to the conventional view, use of chemical fertilizers and pesticides was found to be common in most parts of the valley, and application levels were surprisingly high often exceeding recommended levels. The major exception to this norm is the High Zone, where two-thirds of all potatoes are planted after fallow and hence require less intensive fertilization and pest control (Table 3).

Modern and native varieties

Farmers' use of varieties provides an excellent examples of the complex rationality of Andean agriculture (Brush *et al.*, 1981). Since 1950

TABLE 3
Use of Chemical Fertilizers, Pesticides and Fallow

	Low zone			*Intermediate zone*	*High zone*
	Large farms	*Medium farms*	*Small farms*		
Per cent of potato fields with applications of:					
Chemical fertilizer (N)	100	95	83	74	28
Soil pesticide	89	63	80	90	54
Av. nirogen application (kg ha)	212	124	108	85	148
Per cent of fields planted after fallow	0	8	6	52	67

Source: Franco *et al.* (1979) and Horton *et al.* (1980).

Peruvian plant breeders have released a number of hybrid potato varieties, herein termed 'modern varieties', which are now grown in nearly every potato field in the Low Zone, half the fields in the Intermediate Zone, but only one-fifth of the fields in the High Zone. Native varieties results of the indigenous domestication process have nearly disappeared from the Low Zone, but they are grown on half the potato fields of the Intermediate Zone, and four-fifths of the fields in the High Zone (Fig. 3). Bitter potatoes are a sub-category of native varieties which have high levels of glycoalkaloids. For this reason they are not consumed fresh, but are processed, with age-old methods, into a freeze-dried product known as *chuño* (Werge, 1979). Bitter potatoes are grown primarily in the High Zone.

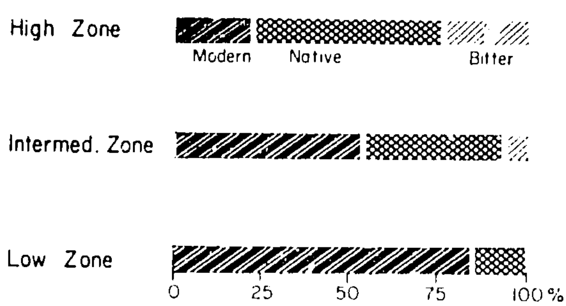

Fig. 3. Cultivation of modern and native potato varieties by agro-ecological zone. Modern varieties are defined herein as hybrids released by Peruvian breeding programs. Native varieties are all those which are not results of formal breeding programs, but of the indigenous domestication process. Bitter potatoes are native varieties which are not consumed fresh but are processed into *chuño*. Percentages refer to the proportion of fields in each type of variety. Data are from Franco *et al.* (1979).

Farmers living in the Intermediate and High Zones were found to prefer native and bitter potatoes to modern varieties, because of their superior adaptation to the ecology and economy of these zones. With present technology, modern varieties have a considerable yield advantage over native and bitter potatoes in the Low Zone, but this is not always the case in the higher zones (Table 4). Native varieties are also less susceptible to frost and hail, and they produce reasonably well with little chemical fertilization and pest control. Hence, their use allows farmers to produce potatoes at high altitudes with a minimum of purchased inputs and low financial risks in case of crop failure (which is quite frequent in these areas).

TABLE 4
Average Yields and Producer Scores for Modern, Native and Bitter Potato Varieties

	Low zone		Intermediate and high zones		
	Modern varieties	*Native varieties*	*Modern varieties*	*Native varieties*	*Bitter potatoes*
Average yield (t/ha)	5·7	3·7	4·8	4·7	4·9
Producer scores for:					
Culinary quality	87	96	76	95	67
Market price	76	84	82	87	58
Yield	80	68	82	73	85
Pest resistance	59	46	66	46	85
Frost resistance	49	35	49	43	91
Storability	65	72	69	85	84

Source: Franco *et al.* (1979).
Notes: Scores range from 0 to 100. A score of zero indicates that all producers considered the variety 'bad'; a score of 100 indicates that all producers considered the variety 'good'. Fewer than five farmers interviewed produced bitter potatoes in the Low Zone; hence no scores are given.

Modern varieties are defined herein as hybrids released since 1950 by Peru's breeding programs. Native varieties are all those which have not originated in formal breeding programs. Bitter potatoes are native varieties which are not consumed directly but are processed into *chuño*.

Two additional advantages of native potatoes are that they store better than modern varieties and they are of higher culinary quality (Brush *et al.*, 1981). Farmers can keep native potatoes for many months, both for seed and home consumption. This is especially important in sparsely populated high areas where rural households have limited cropping alternatives and limited access to retail markets for food and seed.

Andean consumers generally prefer native potatoes to modern varieties. For this reason, many farmers in the Low Zone cultivate small parcels of native varieties for home consumption while they produce higher yielding modern varieties for sale. The market price of native potatoes is generally far above that of modern varieties (Scott, 1981). Hence, in high areas where yields of these two types of varieties are similar, many farmers find it economically attractive to cultivate native potatoes both for household consumption and for sale.

Night frost, sunny days and low relative humidity after harvest provide ideal conditions for processing bitter potatoes into *chuño* in the High Zone. *Chuño* plays a key rôle in the diet of the zone's agricultural and herding people because it is one of the few foods which can be locally produced, and it can be easily stored and transported. The fact that it can be stored for years provides households with a degree of food security in this highly uncertain environment. And, since it is light in weight, it can be easily carried along with herders in their seasonal migrations to high-altitude pasturelands.

Seed quality

Mantaro Valley farmers often consume or sell their largest potatoes and keep the smaller tubers for the next crop's seed. Technologists fault this practice on the grounds that replanting small seed tubers contributes to the spread of yield-reducing virus diseases. (Virus infection increases the proportion of small tubers produced by a potato plant. Hence, in areas where viruses are common, planting small seed tubers can contribute to the spread of virus diseases which decrease yields. For more information on this subject, see Monares (1981) and the references cited therein.) It has been estimated that 100% of farmers' seed is now infected with such viruses (Flores, 1980).

Our surveys and observations indicate that the virus problem is not as serious as it was assumed to be, and that farmers' traditional practices tend to minimize the spread of virus diseases. In the Low Zone, where virus-transmitting insects are most prevalent, about 25% of plants were observed to have visible symptoms of virus infection. In the Intermediate and High Zones, however, virus infection was observed on less than 10% of plants (Franco *et al.*, 1980, 1981). Farmers in the Low Zone were found to renew their seed stocks more frequently than farmers in the higher zones, and they usually sought to obtain seed of good quality from higher areas (Franco *et al.*, 1979; Monares, 1981).

Economics of alternative systems

Survey results illustrate how a traditional potato production system, employing hand implements, native varieties and organic fetilizers, can be more economical than a modern, high-input system. In the Intermediate and High Zones, the *tiepa* system, employing no tillage prior to planting, hand power for all cultivation and harvest operations, native varieties and very little chemical fertilizers and pesticides, was found to be more

TABLE 5
Yields, Costs and Returns in Two Potato Production Systems in the Intermediate and High Zones

	Barbecho *system*[a] ($n = 8$)	Ticpa *system*[b] ($n = 9$)
Yield (t/ha)	9·4	7·3
Total returns (US$/ha)	1 102	1 030
Direct input costs (US$/ha)		
Seed	278	235
Labor	186	218
Pesticides	67	14
Tractor/oxen	64	0
Chemical fertilizer	62	18
Manure	15	59
Total	672	544
Purchased inputs	316	114
Gross margin (US$/ha)		
Total return – direct input cost	430	486
Total return-purchased inputs	786	916

Source: Horton *et al.* (1980).
[a] Modern varieties are grown; tractor is used for plowing.
[b] Native varieties are grown with no tillage before planting; all cultivation is done by hand.

profitable, on average, than the *barbecho* systems, employing tractor power, modern varieties and higher levels of chemical fertilizer and pesticides. With the *ticpa* system, both yields and input costs were about 20% less than with the *barbecho* system. But the gross margin above direct input costs was found to be higher in the *ticpa* system because higher value native varieties were produced. Of equal or greater importance is the fact that the *barbecho* systen. required three times as many purchased inputs as the *ticpa* system. Hence, use of the *ticpa* system allows farmers in the High Zone to produce relatively high net returns, as well as to minimize financial outlay and risks (Table 5).

RESULTS OF ON-FARM TRIALS

The survey results presented above brought into question several common assumptions concerning Andean potato agriculture and factors limiting farmers' yields and incomes. But surveys alone could not provide a test of the performance of recommended practices under farmers' conditions. For this reason a total of 65 experiments were conducted on Mantaro Valley farms in two crop seasons — 1978/79 and 1979/80. This section presents some results of the first year's on-farm trials. More complete reporting is made by Franco *et al.* (1980; 1981).

The trials were planned by a working group consisting of members of the Mantaro Valley Project team, local potato researchers and extensionists. According to the surveys, farmers considered their most important production problems to be pests and diseases, drought, frost and hail (Franco *et al.*, 1979). In contrast, local researchers and extensionists believed that poor seed quality was the main production problem. They placed inadequate fertilization in second place, and poor insect control in third. They believed that yields and net farm returns could be markedly improved through the use of improved seed, increasing and balancing fertilizer applications and better timing and placement of insecticides presently used by farmers. Technologists felt that adequate solutions to the region's hail and frost problems were not available at that time.

Farm-level experiments were designed to test recommended seed, fertilization and insect control measures against current farmers' practices. These inputs were tested in 'low-cost', 'medium-cost' and 'high-cost' technological packages. The individual elements of the packages were also tested on farms in single-factor trials. The experimental results were analysed to determine the recommended technologies' potential for increasing farmers' potato yields and net returns from the crop.

On average, the high-cost technological package increased yields by about 50% over the farmers' level, the low-cost package yielded the same as farmers' established technology and the medium-cost package yielded only about 20% more (Table 6). Hence, the expectation that use of recommended technology could double or triple yields was not fulfilled.

The single-factor trials indicated that, again contrary to expectations, the proposed insect control was the least costly of the recommended technologies, and it produced the highest average rate of return. Improved insect control both increased yield and improved the quality of potatoes harvested in fields infested with the 'Andean tuber weevil' (*Premnotrypes* spp.). This improvement was reflected in an increased unit value of the output and increased net returns. Modified application and dose of chemical fertilizers also offered significant economic benefits, but

TABLE 6
Average Increase in Yield and Cost and Net Benefit Cost Ratio of Technological Packages and Single Factors[a]

	Per cent increase in yield	*Increase in cost (US$/ha)*	*Benefit/Cost ratio*
Technological packages ($n = 11$)			
Low cost	1	48	−0·9[b]
Medium cost	17	165	0·7
High cost	53	252	3·1
Single factors			
Insect control ($n = 5$)	16	48	7·1
Fertilization ($n = 4$)	17	70	4·0
Improved seed ($n = 5$)	17	223	−0·2[b]

Source: Franco *et al.* (1980).
[a] Average increases in yield and cost are in relation to farmer's technology in control treatment of each experiment. Benefit/cost ratio is defined as (change in net returns – change in cost)/change in cost.
[b] Benefit/cost ratio is negative because cost increased but net returns decreased.

at a higher cost. Use of improved seed — the technology considered by researchers and extensionists to be the most critical element in the recommended technological packages — was found to be the costliest of the proposed technologies and the least economic. In fact, its use reduced net returns (see again Table 6).

CONCLUSIONS

The Mantaro Valley research confirmed that potato technology and yields are related to farm size, but not for the assumed reasons. Technology and yields were found to be strongly influenced by ecological and socio-economic factors beyond the control of farmers, many of which had previously been ignored or misunderstood by researchers and extensionists.

Most farmers in the Mantaro Valley were found to be knowledgeable of modern inputs including new varieties and seed, chemical fertilizer and pesticides. The principal barrier to greater adoption of recommended technology did not appear to be farmers' ignorance or traditionalism but the fact that some recommended technologies did not perform well in the field. 'Improved seed' provides a striking example of this point. Use of this input — the central element in recommended technological packages — was found to be unprofitable. Two reasons accounted for this. First, farmer seed was not as poor as technologists had assumed it to be (this was found in the farm surveys and observations). Secondly, available improved seed was not as good as it had been assumed to be (this was found in the experiments).

Researchers and extensionists in crop improvement programs generally believe they are offering superior technology to farmers, and become dismayed at problems of non-adoption. The Mantaro Valley research and the growing body of farming systems research in other developing areas (Casement *et al.*, 1982) indicate that problems of technology transfer may lie more with the inadequacy of the technology than with the indifference of the small farmer. The type of farming systems research conducted in the Mantaro Valley could be used to improve problem identification and the pre-screening of potential solutions in a wide range of agricultural development programs. Rhoades & Booth (1982*a*) and Horton (1983) discuss in greater detail the interdisciplinary research approaches used in the Mantaro Valley Project and their relevance to general problems of agricultural research and development in the Third World.

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